ADAPTIVE CONTROL OF SMART STRUCTURES WITH
TIME VARIANT STIFFNESS AND DAMPING

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Project Objectives and Results

The objectives of this research project were to develop structural control algorithms that addressed a variety of modeling and actuator complexities, such as: uncertainties in structural parameters; time-varying structural parameters; and limited actuator authority. The initial investigation studied use of the LQR/LQG control algorithm; however, the two final years of study were directed towards development of a robust H-infinity control algorithm which considered these complexities.

Significant theoretical development of the robust H-infinity control algorithm is presented in Chase and Smith [1995, 1996]. Robust H-infinity state feedback controllers were developed which addressed the issues of actuator limitations and time varying parametric uncertainties. This research was later extended to include the development of static output feedback H-infinity controllers [Chase, Breneman, and Smith, 1997]. The majority of numerical simulations presented in these investigations involved application of the newly-developed algorithms to actively controlled civil structures in seismic zones. However, the theoretical development behind the algorithms are applicable to any general structural control problems which involve limited actuator capacity and uncertain or time varying structural parameters.

This research resulted in the publication of four journal articles, eight conference papers, and one technical report. A list of these publications is given below. These publications include full theoretical development of the project algorithms as well as detailed descriptions of the numerical simulations performed.

Resulting Journal Publications:

Chase, J. G., Breneman, S. E., and Smith, H. A., 1997, "Robust H-infinity Static Output Feedback Control with Actuator Saturation," submitted for publication in ASCE *Journal of Engineering Mechanics.*

Chase, J. G. and Smith, H. A., 1996, "Robust H-Infinity Control Considering Actuator Saturation, Part 1: Theory," ASCE *Journal of Engineering Mechanics* , Vol. 122, No. 10, pp. 976-983.

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Chase, J. G., Smith, H. A., and Suzuki, T., 1996, "Robust H-Infinity Control
Considering Actuator Saturation, Part 2: Application," ASCE *Journal of
Engineering Mechanics* , Vol. 122, No. 10, pp. 984-993.

Smith, H. A., Chase, J. G., and Wu W.-H., 1995, "Efficient Integration of the Time
Varying Closed-Loop Optimal Control Problem," *Journal of Intelligent Material
Systems and Structures*, Vol. 6, pp. 529-536, August.

Resulting Conference Publications:

Breneman, S. E., Chase J. G., and Smith H. A., 1997, "Robust and LTI H-infinity
Output Feedback Design for Systems with Limited Actuator Authority,"
Proceedings of the *1997 American Control Conference* . June.

Smith, H. A. and Chase J. G., 1996, "Comparison of LQR and H-Infinity Algorithms for
Vibration Control of Structures in Seismic Zones," Proceedings of the *ASCE
Structures Congress XIV*, Chicago, Illinois, April 15-18.

Smith, H. A., Breneman, S. E., and Chase, J. G., 1996, "A Computational Approach for
H-infinity Control of the Exterior Structural-Acoustic Problem," Proceedings of
the *1995 ASME Adaptive Structures and Material Systems Symposium*, ASME
Winter Annual Meeting, San Francisco, California, November.

Chase, J. G. and Smith, H. A., 1995, "Design of H-Infinity Control System Architectures
for Civil Structures," Proceedings of the *10th ASCE Engineering Mechanics
Specialty Conference*, Vol. 2, pp. 1062-1065, Boulder, Colorado, May 21-24.

Wu, W. H., Chase, J. G., and Smith, H. A., 1994, "Inclusion of Forcing Function Effects
in Optimal Structural Control," *Proceedings of the First World Conference
on Structural Control*, Vol. 2, pp. TP2-22 - 30, Los Angeles, California, August.

Smith, H. A. and Chase, J. G. , 1994, "Robust Disturbance Rejection Using H-Infinity
Control for Civil Structures," *Proceedings of the First World Conference on
Structural Control*, Vol. 2, pp. TP4-33 - 42, Los Angeles, California, August.

Chase, J. G., Smith, H. A., and Wu, W.-H., 1994, "Dual Forms and A Proposed
Forward Integration Method for the Matrix Differential Riccati Equation,"
*Proceedings of the 1994 North American Conference on Smart Structures and
Materials*, Orlando, Florida, February 14-16, pp. 332-343.

Smith, H. A., Chase, J. G., and Wu, W.-H., 1993, "Efficient Integration of the
Closed-Loop Time-Varying Optimal Control Problem," *Proceedings of the
Fourth International Conference on Adaptive Structures*, Cologne, Germany,
November, pp. 602-616.

Technical Reports

Chase, J. G. and Smith, H. A., 1995, *H-infinity Control of Civil Structures in Seismic
Zones*, Blume Earthquake Engineering Center Report No. 116, Stanford
University, Stanford, CA.